CUSTOMER NO. 020991

PATENT
**PD-200114**

# CONCURRENT COMMUNICATIONS BETWEEN A USER TERMINAL AND MULTIPLE STRATOSPHERIC TRANSPONDER PLATFORMS



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BACKGROUND OF THE INVENTION

The present invention relates generally to stratospheric transponder platform communications systems. More specifically, but without limitation thereto, the present invention relates to an architecture for communicating between a user terminal and multiple stratospheric transponder platforms.

In future stratospheric communications systems, it is expected that multiple stratospheric transponder platforms will be employed by several service providers to transmit communications signals using the same frequency band. The capability of a user terminal receiver on the ground to access different services from multiple stratospheric transponder platforms is important to the viability of the transponder platform system. Although a phased array antenna at the user terminal may be used to steer the beam from one stratospheric platform to another to avoid signal interference, such antennas are too expensive for the mass consumer market. Similarly, using separate antennas to track each stratospheric transponder platform is not practical for low cost terminals. A method is therefore needed for communicating between a user terminal and multiple stratospheric platforms using low cost antennas that do not require either a tracking mechanism or beam forming circuitry.

## SUMMARY OF THE INVENTION

The present invention advantageously addresses the needs above as well as other needs by providing a method and apparatus for concurrent communications between a user terminal and multiple stratospheric transponder platforms using inexpensive antennas.

In one embodiment, the invention may be characterized as a method for communicating between a user terminal and multiple stratospheric transponder platforms that includes the steps of maintaining a plurality of stratospheric transponder platforms in a substantially fixed position with respect to a user terminal antenna coupled to a user terminal and communicating between the user terminal and at least two of the plurality of stratospheric transponder platforms concurrently.

In another embodiment, the invention may be characterized as a communications system for communicating between a user terminal and multiple stratospheric transponder platforms that includes a user terminal antenna coupled to a user terminal, a gateway hub for interfacing with a plurality of stratospheric transponder platforms having a substantially fixed position with respect to the user terminal antenna for communicating between the user terminal and each of the plurality of stratospheric transponder platforms concurrently.

The features and advantages summarized above in addition to other aspects of the present invention will become more apparent from the description, presented in conjunction with the following drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features and advantages of the present invention will be more apparent from the following more specific description thereof, presented in conjunction with the following drawings wherein:

FIG. 1 is a block diagram of a stratospheric transponder platform communications system for communicating between a user terminal and multiple stratospheric transponder platforms concurrently according to an embodiment of the present invention;

FIG. 2 is a detailed diagram of one of the multiple beams in FIG. 1;

FIG. 3 is a detailed diagram of a single reflector multiple beam antenna according to an embodiment of the present invention for forming two of the beams shown in FIG. 1;

FIGS. 4A and 4B are side views of exemplary feedhorn shapes for the single reflector multiple beam antenna of FIG. 3;

FIG. 5 is a beam plot of the beams formed by the single reflector multiple beam antenna of FIG. 3;

FIG. 6 is a diagram of a communications system according to another embodiment of the present invention for providing multiple data rates;

FIG. 7 is a diagram of a communications system according to a further embodiment of the present invention for accessing multiple Internet routers; and

FIG. 8 is a detailed block diagram of the communications system of FIG. 1.

Corresponding reference characters indicate corresponding components throughout the several views of the drawings.

## DETAILED DESCRIPTION OF THE DRAWINGS

The following description is presented to disclose the currently known best mode for making and using the present invention. The scope of the invention is defined by the claims.

FIG. 1 is a diagram of a stratospheric platform communications system 100 for communicating between a user terminal and multiple stratospheric transponder platforms concurrently. Shown are a gateway hub 101, stratospheric transponder platforms 102, 104, 106, and 108, additional stratospheric transponder platforms 109, a platform orbit 110, a platform separation 112, a platform altitude 114, an antenna axis 150, a point 152 at the center of the formation of the stratospheric transponder platforms 102, 104, 106 and 108, a single reflector user terminal antenna 116, a user terminal 117, and four receiving beams 154, 156, 158 and 160.

In this example, the stratospheric transponder platforms 102, 104, 106 and 108 are communications satellites arranged in a substantially fixed, square formation relative to the user terminal antenna 116 and are separated by the platform separation 112 of about 10 km. Alternatively, unmanned aircraft, antenna towers, and other transponder platforms may be used to suit specific applications. Also, more than one gateway hub 101 may be used in conjunction with one or more of the stratospheric transponder platforms 102, 104, 106 and 108

to communicate with the user terminals 117 via the user terminal antenna 116. User terminal 116 is preferably a single reflector, multiple beam antenna, but may also be separate single reflector antennas. The platform separation 112 of 10 km is computed using a platform altitude of 20 km based on interference considerations. The platform altitude 114 of 20 km is preferable for maintaining each of the stratospheric transponder platforms 102, 104, 106 and 108 in a designated orbit because the average wind velocity is at a minimum at that altitude.

To avoid the requirement of a tracking system to track each of the stratospheric transponder platforms 102, 104, 106 and 108, the platform orbit 110 of each of the stratospheric transponder platforms 102, 104, 106, 108 is maintained in a small circle about 2 km in diameter.

In this arrangement, the stratospheric transponder platforms 102, 104, 106 and 108 relay four separate communications signals concurrently between a user terminal via the user terminal antenna 116 and the gateway hub 101. The spatial diversity of the stratospheric transponder platforms 102, 104, 106 and 108 allows the same frequency band to be shared by the four separate communications signals. Thus, the user terminal 117 is capable of receiving communications signals from the stratospheric transponder platforms 102, 104, 106, 108 using the same frequency band and at the same time. Additional stratospheric transponder platforms 109 may be used to communicate between the gateway hub 101 and the

user terminal 117 as well as with other user terminals in various combinations to suit a variety of applications.

One method by which separate service providers may use the same frequency band without interfering with one another is to provide the user terminal 117 with a separate single beam reflector antenna 118 for each of the stratospheric transponder platforms 102, 104, 106 and 108. Disadvantages of this method include high cost and the labor time involved in setting up each of the four reflectors.

A preferred method is to implement the user terminal antenna 116 with a single reflector multiple beam antenna. The single reflector multiple beam antenna is aimed along an antenna axis 150 to a point 152 at the center of the formation of the stratospheric transponder platforms 102, 104, 106 and 108. In this example, the user terminal antenna 116 forms four beams 154, 156, 158 and 160 that are offset from the antenna axis 150 and aimed at each of the stratospheric transponder platforms 102, 104, 106 and 108 respectively. For example, the beam 154 is aimed at the stratospheric transponder platform 108, the beam 156 is aimed at the stratospheric transponder platform 102, the beam 158 is aimed at the stratospheric transponder platform 106, and the beam 160 is aimed at the stratospheric transponder platform 104.

In this example the beams 154, 156, 158 and 160 are used for receiving, however, in other contemplated arrangements, the beams 154, 156, 158 and 160 may also be used for transmitting communications signals to the stratospheric transponder platforms 102, 104, 106 and 108.

FIG. 2 is a detailed diagram of one of the beams shown in FIG. 1. The description below for the beam 160 is also applicable to the beams 154, 156, and 158. The diameter of the platform orbit 110 and the platform altitude 114 of the stratospheric transponder platform 102 determines a half-power beam width (HPBW) 206 and a reflector diameter 208 of the single reflector multiple beam antenna. Because the diameter of the platform orbit 110 is small compared to the platform altitude 114, the location of the single reflector multiple beam antenna within the service area of the stratospheric transponder platforms 102, 104, 106 and 108 is not critical, as long as the antenna axis 150 points in the direction of the point 152 at the center of the formation of the stratospheric transponder platforms 102, 104, 106 and 108.

An orbit angle 204 subtended by the platform orbit 110 at the platform altitude 114 in this example is approximately 5.5°. To ensure that the stratospheric transponder platform 106 will always be near the peak of the single beam 160, the half-power beam width 206 is preferably twice the platform orbit angle 204 as viewed from the single reflector multiple beam antenna, i.e.,

$$\text{HPBW} \approx 2 \times 5.5^\circ = 11^\circ \qquad (1)$$

This beam width allows the single beam 160 to track the stratospheric transponder platform 106 without a tracking mechanism. The diameter $D$ of the reflector for the single reflector multiple beam antenna may be found by

$$D = 65\ \lambda\ /\ \text{HPBW} \approx 90 \text{ cm} \qquad (2)$$

where $\lambda$ is the wavelength, which is about 15 cm at 2 GHz.

Once the reflector diameter 208 of the single reflector multiple beam antenna is determined, the platform separation 112 between the stratospheric transponder platforms 102, 104, 106 and 108 for forming multiple beams may be determined from interference considerations. For example, a convenient design criterion is that the stratospheric transponder platforms 102, 104, 106 and 108 be at least 2 X HPBW apart to ensure that the signal to interference ratio is at least 20 dB between any two of the beams 154, 156, 158 and 160.

Table 1 below illustrates a typical platform separation vs. beam spacing for the single reflector multiple beam antenna 116 in FIG. 1. As shown in Table 1, increasing the separation between stratospheric transponder platforms 102, 104, 106 and 108 over the range from 8 km to 12 km increases the angle between adjacent beams, or beam spacing, from 22° to 33°.

TABLE 1

| BEAM SPACING | PLATFORM SEPARATION |
|---|---|
| 22°/2 HPBW | 8 Km |
| 28°/2.6 HPBW | 10 Km |
| 33°/3.0 HPBW | 12 Km |

Table 2 below illustrates a typical platform separation vs. signal-to-interference ratio for the single reflector multiple beam antenna 116 in the system of FIG. 1. As shown in Table 2, increasing the platform separation over the range from 8 km to 12 km increases the signal-to-interference ratio from 20 dB to 29 dB.

TABLE 2

| SIGNAL-TO-INTERFERENCE POWER RATIO | PLATFORM SPACING |
|---|---|
| 20 dB | 8 Km |
| 23 dB | 10 Km |
| 29 dB | 12 Km |

FIG. 3 is a diagram of a single reflector multiple beam antenna 300 for forming two of the beams shown in FIG. 1. The other two beams are omitted for clarity, however, the same description applies for adding additional beams. Shown are an antenna mast 302, an antenna mount 304, a tilt angle 306, a tilt arm 308, an antenna axis 310, an antenna reflector 312, an antenna diameter 314, a focal point 316, a focal length 315, two feedhorns 318 and 320, a beam spacing mount 322, and an offset 324.

The antenna mast 302 supports the antenna mount 304. The antenna mount 304 has a tilt angle 306 that may be adjusted by the tilt arm 308 to aim the single reflector multiple beam antenna 300 at the point 152 at the center of the formation of the stratospheric transponder platforms 102, 104, 106 and 108 along the antenna axis 150. The antenna reflector 312 is mounted at one end of the antenna mount 304. The antenna diameter 314 is determined as explained above. The focal point 316 of the antenna reflector 312 is located at a distance equal to the focal length 315 from the antenna reflector 312. The beam spacing mount 322 is mounted at the end of the antenna mount 304 opposite to the antenna reflector 312. The two feedhorns 318 and 320 are positioned on the beam spacing mount 322 so that they are

each displaced from the focal point 316 by the offset 324 to form two separate beams pointed respectively at two of the stratospheric transponder platforms 102, 104, 106 and 108. Additional beams may be formed by adding feedhorns on the beam spacing mount 322 at positions offset from the focal point 316 as described above for the feedhorns 318 and 320.

Locating the feedhorns 318 and 320 offset from focal point 316 to form multiple beams provides a low cost alternative to reflector antennas that locate a single feedhorn at the focal point to form a single beam. Exemplary design values for the single reflector multiple beam antenna 116 are 90 cm for the diameter *D*, 102 cm for the focal length 315, and 22 cm for the offset 324.

FIGS. 4A and 4B are side views of exemplary feedhorn designs for the reflector antenna of FIG. 3. FIG. 4A illustrates a stepped feedhorn 402 having a length 404 and an aperture 406. An exemplary value for both the length 404 and the aperture 406 is 22 cm. FIG. 4B illustrates a stepped and tapered feedhorn 450 having a length 452 and an aperture 454. Exemplary values for the length 452 and the aperture 454 are 27 cm and 22 cm, respectively.

FIG. 5 is a beam plot 500 of multiple beams 502 and 504 formed by the reflector antenna 116 of FIG. 3. The two peak responses 502 and 504 are spaced 22° apart and are representative of any two of the multiple beams 154, 156, 158 and 160. The signal-to-interference noise ratio is 20 dB for a beam spacing of 22° corresponding to a platform orbit diameter of 2 km and a platform separation of 8 km as shown in table 1.

FIG. 6 is a diagram of a communications system 600 for providing multiple data rates. Shown are the gateway hub 101, the stratospheric transponder platforms 102, 104, 106, and 108, the user terminal antenna 116, and the user terminal 117. In this example, the gateway hub interfaces to communications signal sources having separate data rates.

The single reflector multiple beam antenna described above may be used in this example as the user terminal antenna 116. The user terminal antenna 116 is coupled to the user terminal 117 for communicating with the gateway hub 101 using a separate data rate via each of the stratospheric transponder platforms 102, 104, 106, and 108. The user terminal 117 may include signal amplifier / pre-amplifiers (not shown) for pre-amplifying received signals and amplifying transmitted signals from the user terminal 117 according to standard techniques well known in the art. Alternatively, the signal amplifier / pre-amplifiers may be included with the user terminal antenna 116. The user terminal 117 may also include a multiplexer / demultiplexer (not shown) for separating and mixing the communications signals to and from the stratospheric transponder platforms 102, 104, 106, and 108 according to well known techniques. Each of the communications signals may have a separate data rate, and the communications signals may also share the same frequency band concurrently.

FIG. 7 is a diagram of a communications system 700 according to a further embodiment of the present invention for accessing multiple Internet routers concurrently.

The communications system 700 is similar in structure to the communications system 600 in FIG. 6, except that the gateway hub 101 interfaces to the Internet via separate Internet routers. By accessing the Internet through multiple routers, the user terminal 117 can increase data throughput and accommodate individual router and transponder platform failures without interruption of service. If any of the routers or stratospheric transponder platforms should fail, Internet traffic would continue through the operational routers and stratospheric transponder platforms according to standard network management techniques for Internet traffic such as packet assemblers and sequencers.

FIG. 8 is a diagram of a communications system 800 for receiving multiple channels from separate communications service providers concurrently.

The communications system 800 is similar in structure to the communications system 600 in FIG. 6, except that the gateway hub 101 interfaces to separate communications service providers for communicating on multiple channels concurrently using the same frequency band.

Other modifications, variations, and arrangements of the present invention may be made in accordance with the above teachings other than as specifically described to practice the invention within the spirit and scope defined by the following claims.